

# Quasielastic $K^+$ scattering in nuclei\*

A. De Pace

Istituto Nazionale Fisica Nucleare, Sezione di Torino, via Giuria 1, I-10125 Torino, Italy

Quasielastic (QE) studies at intermediate energies are an important tool to study both nucleonic and nuclear physics issues. In particular, the reasons to consider  $K^+$ -nucleus scattering have been twofold. On the one hand, the elementary  $K^+N$  cross section is relatively small compared to other hadronic probes, thus allowing the kaons to penetrate deeper inside the nucleus, making them more suitable to study collective effects. Furthermore, since the  $K^+N$  cross section is dominated by the scalar-isoscalar channel, kaons turn out to be a quasi-pure probe of this mode. On the other hand, the excess of cross section, with respect to multiple scattering theory predictions, that has been found in  $K^+$ -nucleus elastic scattering experiments is still unexplained and may be interpreted in terms of an enhancement of the in-medium  $K^+N$  cross section,  $\sigma_{K+N}$ . This finding has naturally raised the issue of what might be the consequences for QE scattering.

A few results from the experiment performed at BNL, taken from Refs.[1,2], are displayed in Figures 1 and 2. In those papers the data have been compared to calculations in a variety of relativistic nuclear structure models (mean field, Hartree and random phase approximation (RPA), both in nuclear matter and finite nucleus), using a simple reaction mechanism in which the distortion of the strongly interacting kaons is accounted for through an effective number of nucleons participating in the reaction,  $N_{eff}$ , i. e.,

$$\frac{d^2\sigma}{d\Omega d\omega} = N_{eff} \frac{d\sigma_{K+N}}{d\Omega} R(q, \omega), \quad (1)$$

where  $d\sigma_{K+N}/d\Omega$  is the elementary cross section and  $R(q, \omega)$  the nuclear response function. The agreement might look good, but two observations are in order:

- i) In those calculations use has been made of the empirical  $d\sigma_{K+N}/d\Omega$  and of the “experimental”  $N_{eff}$ , the latter having been obtained by integrating the experimental QE cross sections without accounting for any background. The values for  $N_{eff}$  thus obtained are  $\sim 30\%$  higher than Glauber theory predictions. Note that it is rather difficult to interpret this increase of  $N_{eff}$  through a modification of the in-medium  $K^+N$  cross section. A decrease of  $\sigma_{K+N}$  would give rise to a larger  $N_{eff}$ , but should also reflect in a smaller  $d\sigma_{K+N}/d\Omega$ , making QE scattering little sensitive to the

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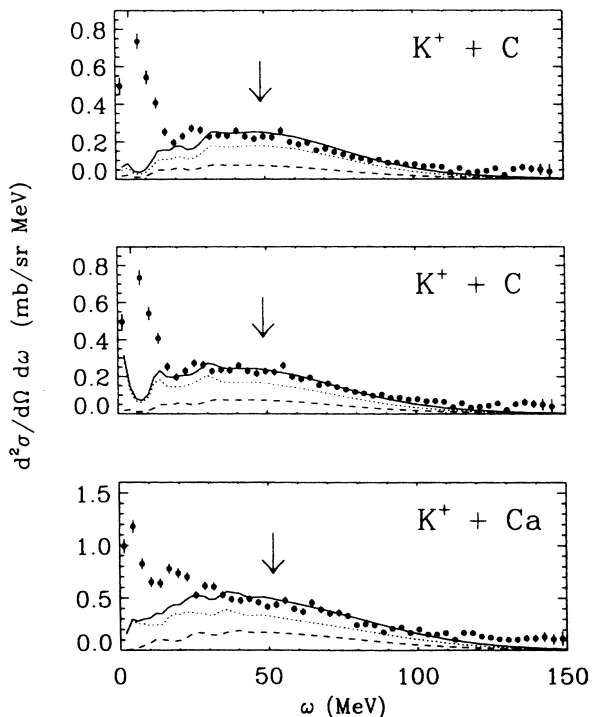


Figure 1. QE cross sections for C and Ca at  $q = 300$  MeV/c from Ref.[1]. The solid lines are the sum of isoscalar (dot) and isovector (dash) responses in a finite nucleus relativistic calculation: Hartree (top), Hartree-RPA (middle and bottom).

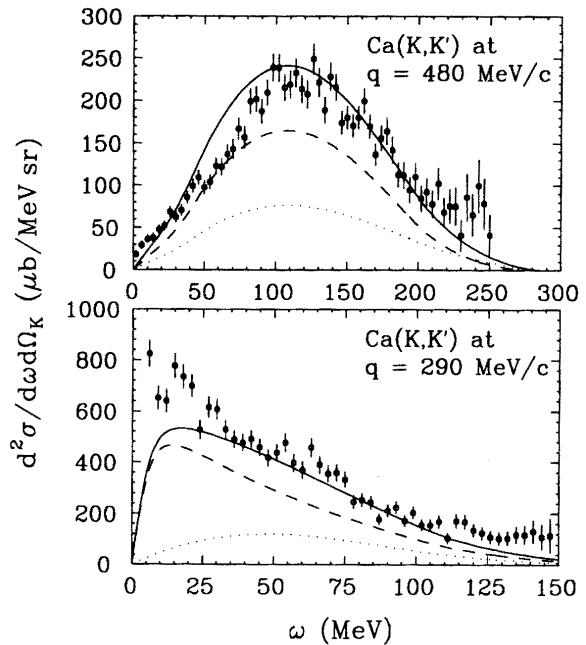


Figure 2. QE cross sections for Ca at  $q = 290$  and  $480$  MeV/c from Ref.[2]. The solid lines are the sum of isoscalar (dash) and isovector (dot) responses in a relativistic Hartree-RPA local density calculation.

in-medium  $K^+N$  cross section [2]. Furthermore, a decrease of  $\sigma_{K+N}$  would be at variance with the findings from elastic scattering.

- ii) Even if one ascribes the larger  $N_{eff}$  to some exotic effect, the agreement of the relativistic models with the data turns out to be good at high momenta (where RPA effects are smaller) and poor at low momenta (where collectivity should be stronger). Although energy transfers below  $\sim 10 \div 15$  MeV should be discarded (since their energy resolution of the experiment is not sufficient to discriminate the elastic contamination), it is clear that the strong distortion of the QE peak observed at low momenta is not reproduced.

In Ref.[3] we have performed a calculation of  $K^+$ -nucleus QE cross sections using a non-relativistic model for nuclear dynamics and an implementation of Glauber theory up to two-step processes. Details of the model can be found in Refs.[3,4]. Here, we briefly enumerate the main steps that have to be taken to get to the QE cross section, starting with the nuclear response functions. The latter are in general proportional to the imaginary part of the polarization propagator, which describes the propagation of density

fluctuations in the nuclear medium [5]:

- The lowest order (uncorrelated) response is given by a mean field described by a Woods-Saxon potential.
- An important class of single-particle correlations is embodied in the *spreading width* of the particle-hole (ph) states (i. e., the coupling of the ph states to higher order configurations). It can be accounted for by introducing a phenomenological complex ph self-energy.
- Although nuclear dynamics is non-relativistic, trivial relativistic kinematical effects can be important at high transferred momenta, so that the correct relativistic kinetic energies should be employed.
- Two-body correlations are introduced through a continuum RPA calculation, using an effective ph interaction based on a  $G$ -matrix [6].  $G$ -matrices are known to give rise to a too strong attraction in the scalar-isoscalar channel. Although there exist many-body schemes that are able to screen the  $G$ -matrix interaction, we have rather tried to see if the data can put constraints on the effective interaction.

The reaction mechanism is based upon an implementation of the Glauber theory up to two steps:

- One-step contributions have been calculated by setting the coupling of kaons to the ph states according to the Glauber prescription, without resorting to the effective number approximation mentioned above. The latter tends to overestimate collective effects, since it rescales in the same way uncorrelated and correlated response functions, without accounting for the fact that the nuclear excitations are generated in the low density peripheral region of nuclei.
- The two-step contribution is much smoother (and, for kaons, turns out to be much smaller) than the one-step term and it can be safely calculated in the effective number approximation, where it is proportional to the effective number of pairs participating in the reaction and to the convolution of two QE responses.

Results are displayed in Figure 3 for  $^{40}\text{Ca}$ . One can see that the strength and the shape of the responses are well reproduced at all momenta. Collectivity manifests itself mainly on the left of the QE peak: as mentioned above, the  $G$ -matrix gives too much attraction; the data seem to point to a reduction of  $\sim 50\%$  of the effective interaction in the scalar-isoscalar channel. Note also the smallness of the two-step term. We also show results using the effective number approximation as in Refs.[1,2]: as anticipated, there is some overestimation of collectivity, but the overall size of the response comes out correctly. Moving along the high energy tail, the calculated cross sections tend to lay more and more below the data, suggesting the presence of a background (as it happens, e. g., in  $(e,e')$  scattering), which would be responsible of the high values for  $N_{eff}$  found in Refs.[1,2].

Finally, note that use of the Glauber predictions for  $N_{eff}$  in the relativistic calculations of Figures 1 and 2 would result in underestimating the data by  $\sim 30\%$ , essentially because

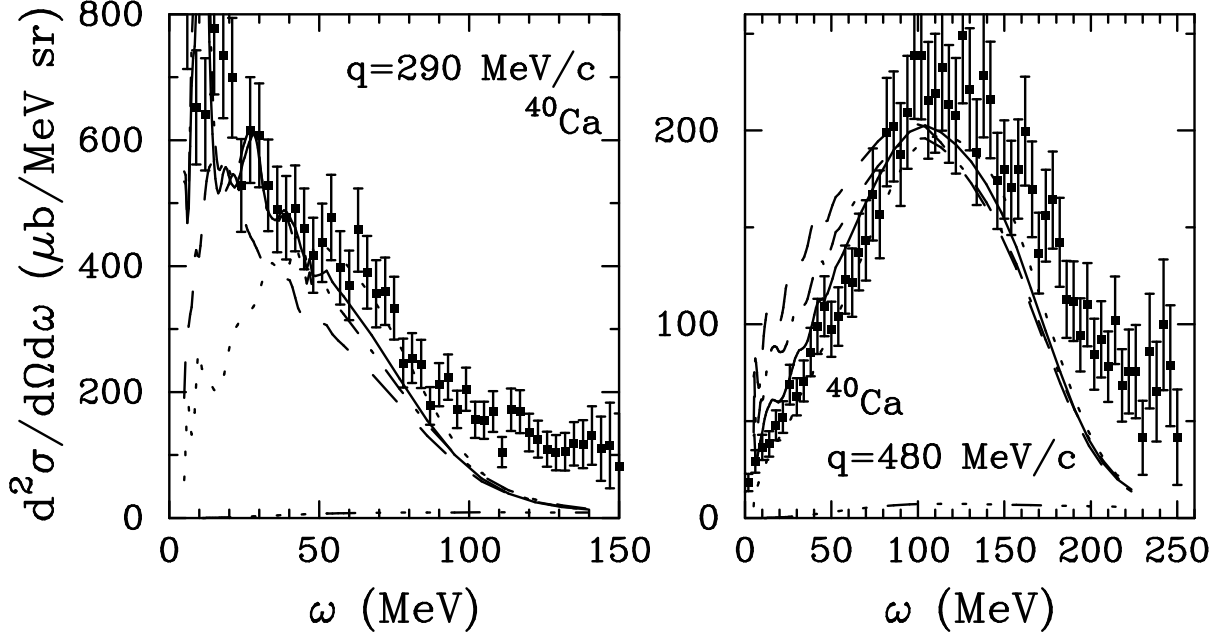


Figure 3. QE cross sections for Ca: Free response (dot); RPA with full  $G$ -matrix (dash); RPA with the scalar-isoscalar interaction reduced by 50% (solid); RPA with the renormalized interaction and the  $N_{eff}$  approximation (dot-dash); two-step contribution (dot-dot-dot-dash).

of the RPA correlations of the relativistic models that quench the response functions, while non-relativistic dynamical models give mainly rise to an enhancement at low transferred energies.

## REFERENCES

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